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# NOISE REMOVAL FROM ECG USING MODIFIED CSLMS ALGORITHM

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## ABSTRACT

ECG signal filtration mainly involves the use adaptive filter as it does not need the signal statistical characteristics. The adaptive filters works on the principle of minimizing the squared Euclidean norm of the difference weight vector under a stability constraint defined over the posteriori estimation error. The input to the adaptive filter is the primary signal i.e. noisy ECG signal and reference input which is the noise that is correlated with the noise in the ECG signal or a signal that is correlated with the ECG in the primary input. The adaptive filter mainly minimizes the mean squared error between these primary input and reference input. LMS, NLMS and CSLMS based adaptive filter have been used to filter the ECG signal and finally we have proposed the Modified CSLMS algorithm and applied on the ECG signal and compared its result with previous Algorithms. The result shows that performance of Modified CSLMS algorithm is better than previous algorithms.

**KEYWORDS:** Adaptive Filter, Noise Cancelation, LMS Algorithm, NLMS Algorithm

## INTRODUCTION

The Electrocardiographic signal (ECG) signal is mainly corrupted due Baseline wander noise and power line interference noise and removal of these disturbances is the initiating step of ECG signal processing. The baseline wander is caused by varying electrode-skin impedance, patient's movements and breath, and power line interference is caused due to addition of 50Hz or 60Hz noise with original ECG signal. These two noises are the dominant noise that adds in the ECG signal and produces the large amplitude in the ECG signal, decreases frequency resolution of ECG signals and degrades the quality of ECG signal and removes the tiny features that are important for the diagnosis of the patient. Hence extraction of low frequency ECG signal from this high frequency noise is the important task of ECG signals processing. Many algorithms have been developed for ECG filtration using both adaptive and non adaptive filters techniques. The non adaptive filter techniques require the statistical characteristics of the signal and its coefficients are fixed and cannot be updated again and again, but adaptive filters does not requires statistical characteristics of the signal, and allows to detect the time varying potentials and its coefficients can be updated depending on the errors.

Thakor et al in [3] shows the LMS based adaptive recurrent filter which calculates the impulse response of normal QRS complexes and this response is used for arrhythmia detection in Ambulatory ECG recordings and in [4] Costa and Bermudez showed the noise resilient variable step size LMS algorithm. Besides LMS algorithm, the NLMS algorithm with different variations have been published such as Ching - An Lai in [5] proposed the NLMS algorithm with decreasing step size for adaptive filters.

Other than LMS, NLMS there is constrained stability least mean square algorithm which is based on the minimization of the difference weight vector under stability constraints which is defined over posteriori estimation errors. This algorithm aims at minimizing the mean squared error between the primary input and the reference input. In order to improve the performance of the CSLMS algorithm we presented Modified CSLMS Algorithm which adaptively adjusts the step size based on the error signal which results in faster convergence and stable algorithm.

Finally, to show the performance of all these algorithms we have taken the ECG signal and corrupted it first with Baseline wander noise and estimated the ECG signal and second time ECG signal is corrupted with the power line noise and again the ECG signal is recovered by using these all algorithms. To improve our analysis we calculated and compared the signal to noise ratio and Mean square error of extracted ECG signal using LMS, NLMS, CSLMS and Modified CSLMS algorithm.

**Proposed Implementation**

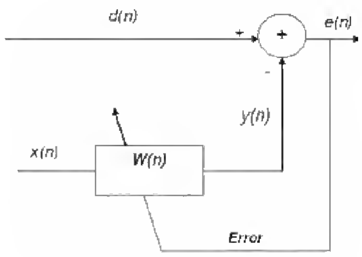



**Figure 1: Adaptive Filter Structure**

Above figure shows the basic adaptive filter structure which takes the input *d(n)* which the ECG signal corrupted with the noise and another input to the filter is *x(n)* which is the noise that is correlated with noise in the ECG signal input signal.

If we consider the filter length to be $L$, then LMS algorithm updates the filter coefficient as given below

$w(n + 1) = w(n) + \mu x(n) e(n)$,

where, $w(n) = [w_1(n), w_2(n) \cdots w_{L-1}(n)]^t$ is the tap weight vector at the $n^{th}$ index, $x(n) = [x(n)\ x(n-1) \cdots x(n-L+1)]^t$,

The error signal can be calculated as

$e(n) = d(n) - w^t(n)\, x(n)$

The filter output can be calculated as,

$y(n) = w^t(n) x(n)$,

Besides LMS algorithm, The Normalized LMS algorithm is also used to update the adaptive filter coefficient which considers the variation in the signal level at the filter output and selects the normalized step size parameter which results in a stable as well as fast converging algorithm.

The NLMS Algorithm update filter coefficient as given below

$$w\,(n+1)=w(n)+\left[\frac{\mu}{P+x^{t}(n)x(n)}\right] x(n)\, e(n),$$

Where,

$$\mu\,(n)=\frac{\mu}{P+x^{t}(n)x(n)}$$

$\mu$ is the convergence factor.

The major drawback associated with LMS and NLMS algorithm is that the mean square error between estimated signal and original ECG signal is large due to which there is the distortion in the estimated output.

The CSLMS Algorithm makes use of variable step size in which, step size is inversely proportional to the square of the difference between the two consecutive input vectors. The CSLMS algorithm updates the filter coefficient as

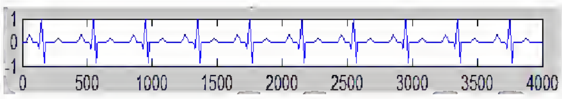
$$W\,(n+1) = w(n) + \mu\left[\frac{\delta x(n)\delta e(n)}{p+\|\delta x(n)\|^{2}}\right]$$

Where, $\delta x(n) = x(n) - x(n\text{-}1)$ represent the difference between two consecutive input data vectors and $\delta e(n) = e(n) - e(n\text{-}1)$ represent the difference in the priori input sequence, the parameter $p$ is used to avoid denominator being too small.

## SIMULATION RESULTS

### Baseline Wander Reduction

To show the results of these algorithms the ECG signal is corrupted with the real baseline wander noise taken from MIT-BIH Noise Stress Test Database (NSTDB) is applied as primary input to the filter and Baseline wander noise is given as reference input, and different filter structure is developed using LMS, NLMS and CSLMS algorithm and ECG signal is recovered which is shown in Figure 2 and Table.1 and Table .2 shows the SNR and MSE calculation for all algorithm respectively.

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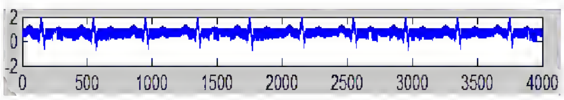


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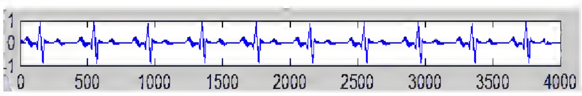


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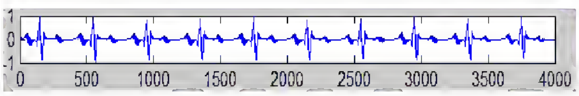



(d)

(e)

**Figure.2: Results of Base Line Wander Reduction (a) Pure ECG Signal, (b) ECG with Real Baseline Wander, (c) Recovered Signal Using LMS, (d) Recovered Signal Using NLMS, (e) Recovered Signal Using CSLMS**

**Table.1 SNR Calculation for Base Line Wander Reduction LMS, NLMS and CSLMS Algorithm**

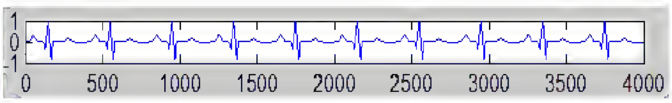
| Sr. No. | Algorithms | SNR |
|---|---|---|
| 1. | LMS algorithm | 0.0568 |
| 2. | NLMS algorithm | 0.0588 |
| 3. | CSLMS algorithm | 0.0710 |

**Table.2 MSE Calculation for Base Line Wander Reduction LMS, NLMS and CSLMS Algorithm**

| Sr. No. | Algorithms | MSE |
|---|---|---|
| 1. | LMS algorithm | 0.0016 |
| 2. | NLMS algorithm | 0.0028 |
| 3. | CSLMS algorithm | 2.9153e-006 |

**Power Line Interference Canceller**

The power line noise can be modeled by using sine wave having the frequency of 50 Hz, and in order to show the result of power line interference cancellation ECG signal is corrupted with sine wave having frequency of 50 Hz and this corrupted ECG signal is applied as primary input to the filter and sine wave is applied as reference input to the filter. The ECG is recovered using LMS, NLMS, and CSLMS algorithm shown in Figure 3. And for better analysis of the estimated ECG signal the corresponding SNR and Mean Square Error is calculated for the estimated ECG signal which is shown in the Table.3 and Table.4 respectively.



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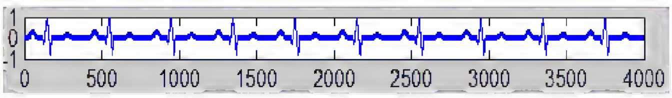

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**Figure 3: Results of Power Line Interference Cancelation (a) Pure ECG Signal, (b) ECG with Power Line Noise, (c) Recovered Signal Using LMS, (d) Recovered Signal Using NLMS, (e) Recovered Signal Using CSLMS**

**Table.3: SNR Calculation for Power Line Interference Cancelation LMS, NLMS and CSLMS Algorithm**

| Sr. No. | Algorithms | SNR |
|---|---|---|
| 1. | LMS algorithm | 22.1642 |
| 2. | NLMS algorithm | 54.5958 |
| 3. | CSLMS algorithm | 100.2943 |

**Table.4: MSE Calculation for Power Line Noise Cancelation Using LMS, NLMS and CSLMS Algorithm**

| Sr. No. | Algorithms | MSE |
|---|---|---|
| 1. | LMS algorithm | 5.9418e-008 |
| 2. | NLMS algorithm | 7.6209e-008 |
| 3. | CSLMS algorithm | 1.3456e-009 |

From the above results the CSLMS algorithm shows better results as compared LMS and NLMS algorithm, but the Modified CSLMS algorithm can also be used for filtration of ECG signal which makes use of variable step size to achieve better stability and faster convergence rate. The Modified CSLMS updates the filter coefficients as given below

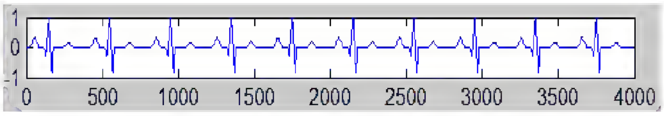
$$W(n+1) = w(n) + \mu(n)\left[\frac{\delta x(n)\delta e(n)}{p+\|\delta x(n)\|^2}\right]$$

Based on the error the variable step size can calculated as

$$\mu(n) = b(1 - \exp(-a|e(n)|^2))$$

Where, $a$ and $b$ are the two adjustable parameters. The two parameters can provide better balance between convergence speed and steady state maladjustment by changing the step size.

In order to show that Modified CSLMS has better performance as compared to CSLMS algorithm, the ECG signal is corrupted with the base line wander noise and applied to adaptive filter which makes use of CSLMS and Modified CSLMS algorithm and ECG signal estimated shown in Figure 4. And Table.5 and Table.6 shows the SNR and Mean Square Error calculation using both the algorithm. Then ECG signal is corrupted with Power line noise and ECG signal is estimated using CSLMS and Modified CSLMS and output is obtained which is shown in Figure 5. And Table.7 shows the SNR calculation and Table.8 shows the Mean square Error calculation using CSLMS and Modified CSLMS algorithm.

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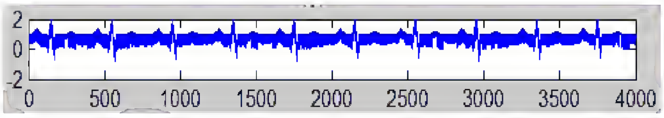


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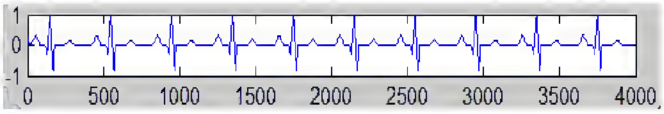


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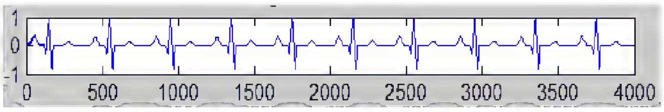



(d)

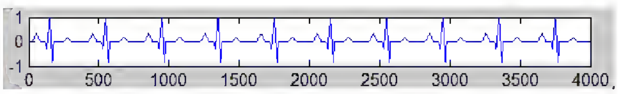
**Figure 4: Results of Base Line Wander Reduction (a) Pure ECG Signal, (b) ECG with Real Baseline Wander, (c) Recovered Signal Using CSLMS, (d) Recovered Signal Using Modified CSLMS**

**Table 5: SNR Calculation for Base Line Wander Reduction Using CSLMS, MCSLMS Algorithm**

| Sr. No. | Algorithms | SNR |
|---|---|---|
| 1. | CSLMS algorithm | 0.0702 |
| 2. | MCSLMS algorithm | 0.0704 |

**Table 6: MSE Calculation for Base Line Wander Reduction Using CSLMS, MCSLMS Algorithm**

| Sr. No. | Algorithms | MSE |
|---|---|---|
| 1. | CSLMS algorithm | 1.6404e-007 |
| 2. | MCSLMS algorithm | 6.3777e-008 |

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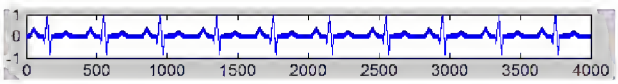


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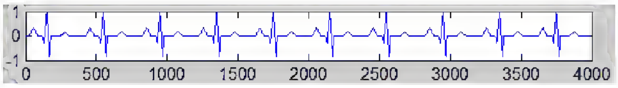


(d)

**Figure 5: Results of Power Line Cancelation (a) Pure ECG Signal, (b) ECG with Power Line Noise, (c) Recovered Signal Using CSLMS, (d) Recovered Signal Using Modified CSLMS**

**Table 7: SNR Calculation for Power Line Noise Cancelation Using CSLMS, MCSLMS algorithm**

| Sr. No. | Algorithms | SNR |
|---|---|---|
| 1. | CSLMS algorithm | 8.2258 |
| 2. | MCSLMS algorithm | 8.2669 |

**Table 8: MSE Calculation for Power Line Noise Cancellation Using CSLMS, MCSLMS Algorithm**

| Sr. No. | Algorithms | MSE |
|---|---|---|
| 1. | CSLMS algorithm | 1.2510e-009 |
| 2. | MCSLMS algorithm | 5.2841e-008 |

## CONCLUSIONS

In this paper the methods of noise removal from ECG signal using LMS, NLMS, CSLMS, and Modified CSLMS based filter is shown and corresponding results are shown. The results of our simulation confirms that Modified CSLMS algorithm is better than LMS, NLMS and CSLMS algorithm for removal of both Base line wander noise and Power line noise the only disadvantage of Modified CSLMS algorithm is larger Mean square error for Power line noise interference than CSLMS algorithm, but SNR for Modified CSLMS is greater than CSLMS algorithm and hence even though, the LMS and NLMS based filters are primarily used for ECG signal filtration the CSLMS and Modified CSLMS algorithm can also be used for filtration of ECG signals.

## REFERENCES

1. Guodong Song, Guangyuan Liu, Wei Liu, Zhengji Long and Shiyuan Wang “A Modified CSLMS algorithm and Its application in Chaos Communication” 2012 5th International conference on Image and Signal Processing.
2. Y. Der Lin and Y. Hen Hu, "Power-line interference detection and suppression in ECG signal processing, "IEEE Transactions on Biomedical Engineering, vol. 55, pp. 354-357, January, 2008.
3. N. V. Thakor and Y. S. Zhu, "Applications of adaptive filtering to ECG analysis: noise cancellation and arrhythmia detection," IEEE Transactions on Biomedical Engineering, vol. 38, no. 8, pp. 785-794, August, 1991.
4. M. H. Costa and 1. C. M. Bermudez, "A noise resilient variabIe step-size LMS algorithm, "Signal Processing, voI. 88, pp. 733-748, 2008.
5. Ching-An Lai, "NLMS algorithm with decreasing step size for adaptive IIR filters, "Signal Processing, vol. 82, pp. 1305-1316, 2002.

6. S.C. Douglas, “A family of normalized LMS algorithms” IEEE signal processing Lett., Vol. 1, no. 3, pp.49-51, 1994.
7. A. I. Sulyman and A. Zerguine, "Convergence and steady-state analysis of a variable step-size NLMS algorithm;' Signal Processing, vo1.83, pp.1255-1273, 2003.
8. H. Simon, Adaptive filter theory, Prentice-Hall, 2001.
9. Digital Signal Processing by J.G. Prokis and D.G. Manolakis: Prentice Hall, 3rd Edition, 2000.